NEER Grant Progress Report
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High Pressure Xenon Gamma Ray Spectrometers for Field Use
University of Michigan
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Introduction

There is an on-going need for instruments that can be used in the field for gamma ray spectrometry with improved energy resolution. The common detectors now used for this purpose are based on scintillators, and are limited to energy resolution figures of about 6% measured at 662 keV. Germanium detectors can provide an outstanding energy resolution of 0.3% or less at this energy, but require cooling with liquid nitrogen that often interferes with their field use. We are pursuing an alternative that is capable of producing an energy resolution that is intermediate between these two widely used instruments, and that does not require cooling so that its application is not restricted by this operational disadvantage. An energy resolution of about 2% or better is potentially achievable using a pressurized xenon-filled ion chamber operated at room temperature. This improvement over scintillators would permit a wide class of measurements that are not now possible without the burden of liquid nitrogen cooling.

The performance of the traditional ion chamber with a Frisch grid is often limited by microphonic noise generated by vibrations common in field applications. We have designed and fabricated a new type of ion chamber that does not require a grid. The function of the traditional Frisch grid has been accomplished by employing a unique dual anode system capable of single polarity charge sensing. Since both anodes are fabricated on the surface of a solid rod

and the Frisch grids are absent, this approach provides a means of eliminating the noise sources associated with the vibration of the grids.

Gas-filled detectors operated at near-atmospheric pressure have extremely low efficiency for direct gamma ray detection in the gas. Furthermore, the range of secondary electrons in such gases is large, and few are fully absorbed in the gas. However, by operating the gas at a high pressure, both of these limitations can be overcome, and our modeling calculations indicate that a useful detection efficiency will result.

To expedite the fabrication of the chambers, we are working in collaboration with Dr. Gary Tepper of Virginia Commonwealth University. Dr. Tepper has extensive experience in the fabrication and filling of high-pressure ion chambers of conventional design, and has assembled the gas handling system needed to purify and transfer the xenon gas to the assembled chambers. A great deal of care must be taken to assure clean conditions within the chamber before filling, and the xenon gas must be purified to a high degree before it is suitable for use in the chamber. The first detector we are now beginning to test is a 2.65 l cylindrical chamber using highly purified xenon gas operating at a pressure of up to 57 atm (see Fig. 1).

Progress made during FY99-00

Over the course of the past year, the initial design of the high pressure xenon detector has been completed and two identical detectors have been constructed (see Fig. 2). Particular emphasis was placed on the design of the anode (see Fig. 3). To achieve the goal of single polarity charge sensing without using a Frisch grid, a novel dual anode system was designed that

is the analog of "coplanar anodes" recently developed for use with semiconductor detectors. These anodes consist of two interleaved helices of wire located on the surface of an insulating rod. The two different anodes are held at a slight potential difference (typically $\Delta V = 50\text{-}100$ V). In this way, all the ionization electrons are directed to only one of the two anode wires. When the electrons are moving far from the anodes, each wire feels about the same induced charge. However, when the electrons approach the anode surface, one of the anode signals rises sharply while the other drops to zero. By electronically subtracting the two anode signals, a short-duration pulse is derived whose amplitude reflects only the number of collected electrons and is nearly completely independent of their position of origin. Also, because the slowly moving positive ions move away from the anode, their motion has almost no effect on the difference signal. In the case of semiconductors, this coplanar anode configuration has resulted in significant improvements on the energy resolution since the signal is not dependent on the collection of the slowly-moving holes. Our goal is to demonstrate that the same principle can be applied in high pressure gas detectors.

In addition to the development of the detectors, acquisitions have been made to create a laboratory environment suitable for evaluating the high pressure xenon detectors. Equipment was purchased to meet these needs including a series of AmpTek Inc. A250 charge-sensitive preamplifiers; an Ortec 672 spectroscopy shaping amplifier; an Ortec Trump-PCI 8k MCA with software; an Ortec 4001A NIM bin; a Bertan High Voltage power supply with cables and connectors; an Agilent Technologies 54825A digital oscilloscope; and a Dell Optiplex 550MHz computer.

When the physical fabrication and assembly of the two detectors were completed in March of this year, they were filled with research grade xenon (i.e. xenon that is approximately 99.9% pure) which was passed through a spark chamber for additional purification. It was decided that each detector would be filled to different density to explore the effect of gas density on performance. Hence, one detector was filled at 0.4 g/cm^3 and the second at 0.6 g/cm^3.

Because of the low level of the signal pulses expected from the chamber, the supporting electronic components were assembled with careful attention to noise and pickup concerns. Two different sets of electronics components were required for this detector. First, a simple high voltage low-pass filter was fabricated for the cathode side of the detector. A high degree of filtering was required due to the nature of high voltage power supplies which frequently have significant AC fluctuations. The second electronics box houses the preamplifiers and subtraction circuit necessary for obtaining the energy information required by the coplanar anode mode of operation.

The first detector has been tested at voltages up to 6 kV in order to determine if sparking will be a problem. Initially there was some difficulty with sparking between the cathode feedthrough wire and the detector casing. In order to solve this problem, a Teflon sleeve was machined to fit over this connector. The problem appears to have been solved by this fix and the detector has been able to run spark-free at 6 kV.

We have only recently begun to set up the measurements to record signals from gamma-ray induced events in the chamber. Efforts are now underway to extract the various signals from the anodes and difference circuits, and to investigate methods to maximize the signal/noise ratios to permit recording of our first gamma ray spectrum.

Plans for FY00-01

We expect to begin gathering data very soon on the performance of the first two chambers that have been constructed. We fully expect that results from the first designs will be far from optimal, and will invest a major effort in isolating the major sources of noise and other factors that will limit their energy resolution. Techniques to be employed will include analyzing in detail the pulse shapes measured using the digital oscilloscope from each of the two anodes independently, as well as the behavior of the difference signal as the applied voltage and inter-anode voltages are varied. We plan to compare the results of the measurements with those from predictive models based on the Schockley-Ramo theorem for induced charges, and to use any differences as a diagnostic aid in understanding the details of the electron transport within the chamber.

We plan to construct at least two additional chambers in the coming year that will incorporate design changes suggested by the results of these initial evaluations. Our goal is to maximize the signal-to-noise ratio to achieve the best possible energy resolution from the

detector. Again, we will work in close collaboration with Dr. Tepper and continue to make use of his excellent facilities for the fabrication and filling of the new chambers.

Figure 1. The prototype high pressure xenon gamma ray spectrometer .

Fig. 2: Schematic of high pressure Xe detector
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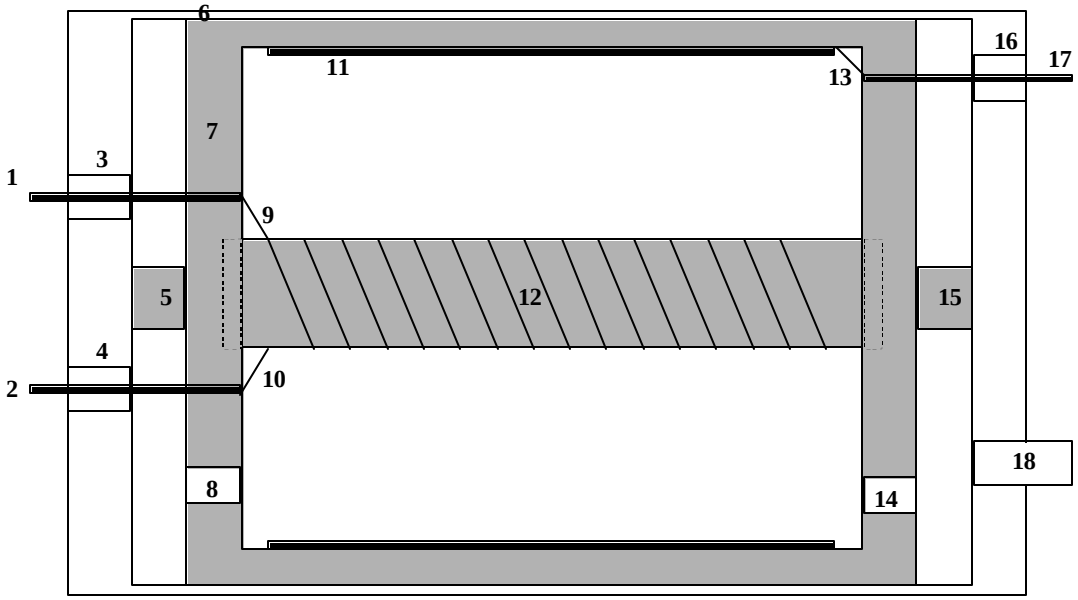
(Not shown to scale)



1. Anode #1 output wire
2. Anode #2 output wire
3., 4. Ceramaseal feedthrough #9791-04-W
5. Macor ceramic spacer
6. 1 mm stainless steel wall
7. Macor ceramic
8. 1/4” pump out port
9. Spring tab connector for anode #1
10. Spring tab connector for anode #2
11. Cathode shell (silver)
12. Anode rod
13. Spring tab connector for cathode
14. 1/4” pump out port
15. Macor ceramic spacer
16. Ceramaseal feedthrough #9791-04-W
17. Cathode high voltage input wire
18. Valve for gas fill

Fig. 3: Schematic of anode rod for high pressure Xe detector
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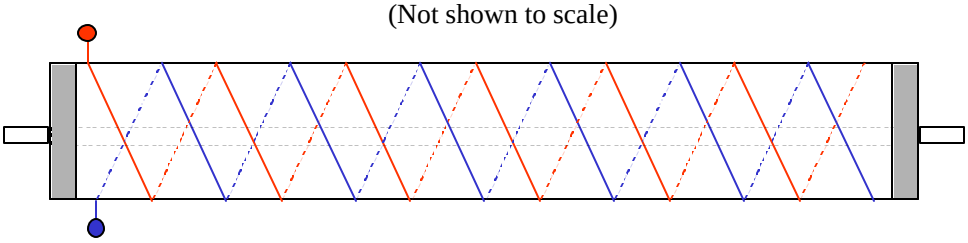
(Not shown to scale)



Dual electrodes in helical formation around anode rod.
Anode rod supported by 5 mm thick metal rod.
Metal electrode contacts 180º apart.
Rod diameter = 1 inch
Electrode diameter = 2 mm
Gap between electrodes = 2 mm
Strip width = 300 μm
Insulating end cap thickness = 0.5 mm